Enabling Advanced Electrode Architecture through Printing Technique

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Project ID: bat556

Overview

Timeline

- Start date: Sept. 30, 2020
- End date: Nov. 30, 2023
- Percent complete: 30%

Budget

- Total project funding: $11,996,209
  - DOE share: $9,596,965
  - Contractor share: $2,399,244
- Funding for FY 2021: $4,606,732
- Funding for FY 2022: $3,998,128

Barriers and Technical Targets

- Cost
  - Cost of high-energy Li-ion batteries is approximately $200 - $300/kWh (usable energy)
  - High manufacturing cost
- Performance
  - Existing chemistries (graphite anodes paired with transition metal oxides cathodes need improvement in XFC to match gas-powered and vehicles' performance and customer convenience

Partners

- Argonne National Laboratory, Brown University, Nanoramic Laboratories, Northeastern University, The University of North Carolina at Charlotte, SafeSense Technologies LLC
- Project lead: Western Michigan University

Relevance

Impact

- A novel, low cost and high throughput printing technique to manufacture electrode
- A method to scale up printed electrode production
- Printed electrodes with precisely controlled porous architecture for fast charging batteries

Objectives

- Identify an ink for printing electrode for fast charging batteries
- Identify a printing process for fabricating electrodes for fast charging batteries
- Demonstrate a 15 cm × 4 cm printed electrode with porosity varied along the thickness direction
- Demonstrate a 15 cm × 4 cm printed electrode with patterned and straight pore channels
- Demonstrate a printed electrode with >50% improvement in the rate capability over the baseline commercial electrode

Milestones

Time	Description of Milestone or Go/No-Go Decision	status
Nov. 2020	Complete experimental setup	Complete
Feb. 2021	Identify an ink for printing negative electrode	Complete
May 2021	Demonstrate a 15 cm × 4 cm printed electrode with porosity varied along the thickness direction	Complete
Aug. 2021	Demonstrate a 15 cm × 4 cm printed electrode with patterned porous structure	Complete
Nov. 2021	Demonstrate a printed electrode with >50% improvement in the rate capability over the baseline commercial electrode	Complete
Feb. 2022	Print an optimized electrode through a process with throughput of 2 m^2/min	On schedule
May 2022	Build a theoretical model to predict the effect of porous architecture on behavior of printed electrode	On schedule
Aug. 2022	Demonstrate a cell containing printed electrode with the capacity retention of >80% at 4C	On schedule
Nov. 2022	Demonstration of a 20 mAh pouch cell with printed electrodes	On schedule

Approach

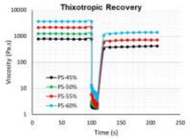
We propose to enable advanced electrode architecture through printing techniques. The high throughput printing process will significantly lower the cost of electrode manufacturing. The advanced electrode architecture will enable energy-dense electrodes fast charging capability.

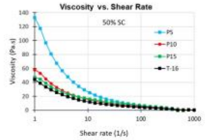
- Develop anode and cathode inks suitable for printing process
- Develop an appropriate printing process for electrode fabrication
- Build theoretical model to guide electrode structure design for fast charging batteries
- Produce electrodes at pilot scale
- Validate printed electrodes in batteries for fast charging application

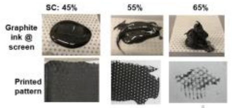
Accomplishment to Date FY 2022

Graphite ink
Solid content (SC): 45%
Surface tension: 24.4 mN/m

Graphite inks:
- Shear thinning behavior
- 50-55% SC suitable for printing

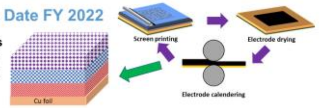






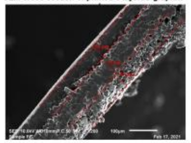
Accomplishment to Date FY 2022

Printed graphite electrodes demonstrated the porosity varied along the thickness direction



Printed 3 layered graphite anode

SEM cross section of printed 3 layered graphite



Accomplishment to Date FY 2022

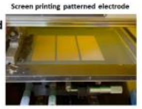
Electrodes with well-controlled channels were produced through printing processes

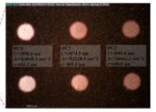
Ave. Pore Size: ~86 μm

Ave. Pore Size: ~490 μm

Printed graphite electrodes with varied pore sizes

Screen printing patterned electrode

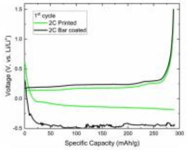


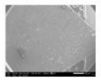


Ave. Pore Size: ~983 μm

Accomplishment to Date FY 2022

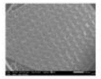
Printed electrodes demonstrated promises in stabilizing battery performance and suppressing Li plating at high rates





Bar-coated graphite electrode after 2C rate test

White particles are identified to be Li dendrites



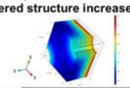
Printed graphite electrode after 2C rate test

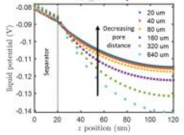
No Li dendrites are detected

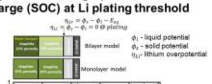
- Both anode and cathode with patterned pore channels and varied porosity were printed
- Printed electrodes exhibited stable battery performance up to 2C
- Printed electrodes alleviated Li plating at 2C

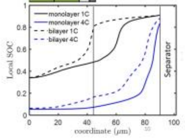
Accomplishment to Date FY 2022

Guidance from theoretical models in electrode design:
- Shorter pore distance decreases potential gradient in the graphite electrode
- Layered structure increases the state of charge (SOC) at Li plating threshold

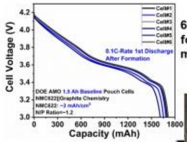






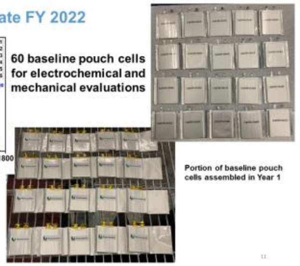


Accomplishment to Date FY 2022



Discharge voltage profiles of representative baseline pouch cells

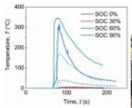
60 baseline pouch cells for electrochemical and mechanical evaluations

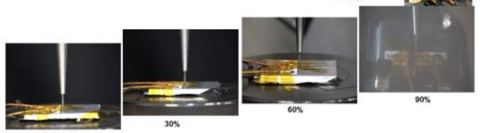


Portion of baseline pouch cells assembled in Year 1

Accomplishment to Date FY 2022

Nail penetration tests on baseline pouch cells:
- A sharp voltage drop happened after the fracture
- Smoking & explosion observed at >60% SOCs





SOC: 0%

30%

60%

90%

Responses to Previous Year's Reviewers' Comments

- This is the first year that the project has been reviewed

Collaborations

- **Argonne National Laboratory** (*W. Lu*) – Li dendrite investigation, Electrode design
- **Brown University** (*B. Sheldon, K. Kim*) – Modeling, Mechanical degradation investigation
- **Nanoramic Laboratories** (*B. Cao*) - Cathode ink development, Pouch cell fabrication
- **Northeastern university** (*H. Zhu*) – Printed cathode development
- **SafeSense Technologies LLC** (*B. Narakathu*) – Pattern roll/template development
- **The University of North Carolina at Charlotte** (*J. Xu*) – Multiphysics modeling development. Pouch cell evaluations
- **Western Michigan University** (*M. Atashbar, M. Atilhan, B. Bazuin, C. Burns, K. Li, A. Pekarovicova*) – Anode ink development, Printing process development

Remaining Challenges and Barriers

- **Printing patterned electrode with high throughput**
  - Understanding dependence of printing quality on printing conditions and ink property
  - Understanding the key factors controlling the scale up printing process
  - Printed electrodes with designed porous structure
  - Preservation of porous structure in electrode obtained at high speeds
- **Electrode structure for fast charging application**
  - Effect of porous structure on suppressing Li plating
  - Structural evolution of printed electrodes during cycling
  - Dependence of battery performance on the properties of printed electrodes

Proposed Future Research (FY 22-23)

- **FY 2022: Optimization of printing process and electrode design**
  - Optimize printing process for anode and cathode fabrication
  - Increase printing speed
  - Build theoretical model to illustrate the structure-to-property relationship in printed electrodes
  - Initialize pouch cell design and build
  - Validate cell components for large format cell assembly
- **FY 2023: Manufacturing electrode scale up and cell build**
  - Scale up printing process
  - Produce printed electrodes with optimized porous structure at pilot scale
  - Fabricate and test 2Ah pouch cells with printed electrodes
  - Develop design concept and estimate cost of prototype large format pouch cell system

Any proposed future work is subject to change based on funding levels

Summary

- Identified inks for printing both anodes and cathodes
- Demonstrated s printed electrode with porosity varied along the thickness direction
- Demonstrated a printed electrode with patterned and straight pore channels
- Demonstrated a printed electrode with >50% improvement in the rate capability over the baseline commercial electrodes

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